Rooftop solar has significant potential, but it can cause issues for grid operations. The experience in Australia shows there are practical solutions emerging that are of benefit for both the grid operator and the end consumer

Energy Transition Masterclass
Session 6 - Recap on Key Message

OPERATION OF ELECTRICITY GRIDS

Dr. Elizabeth Ratnam
Australian National University
May 5th, 2022

ENERGY TRANSITION ROUNDTABLES
Energy Transition Masterclass

ENERGY TRANSITION PARTNERSHIP
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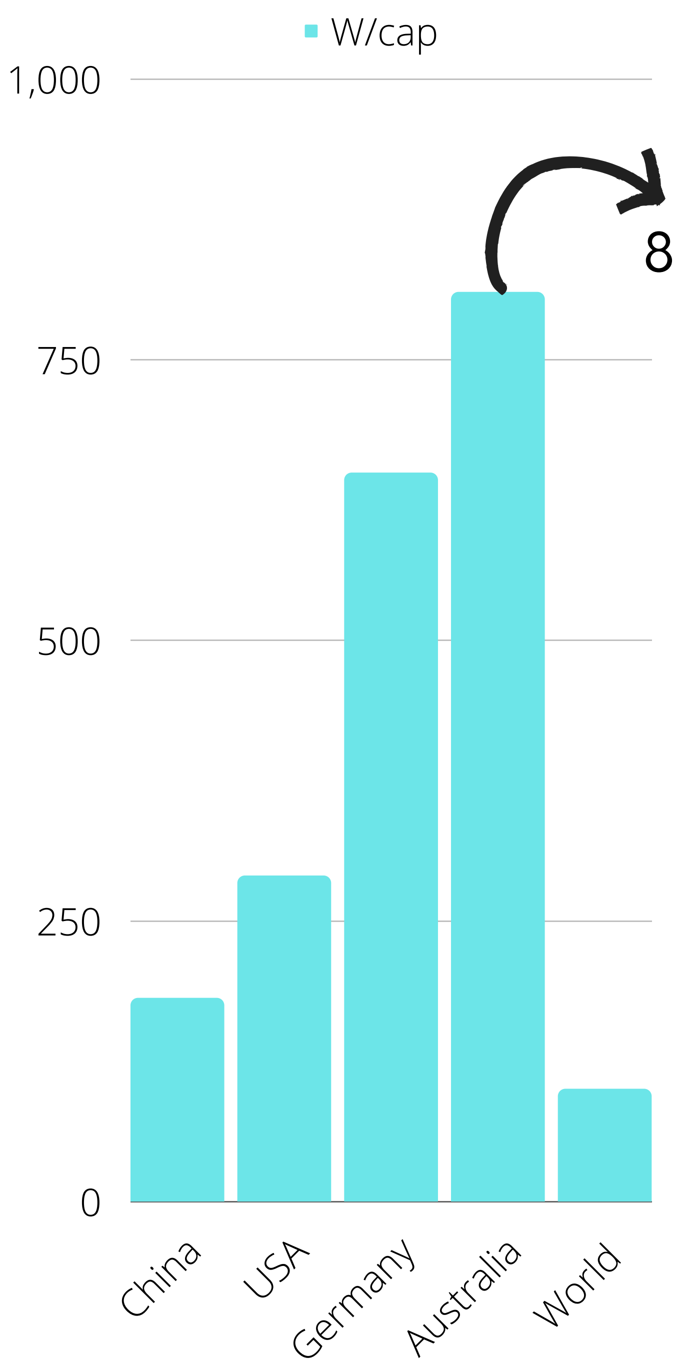
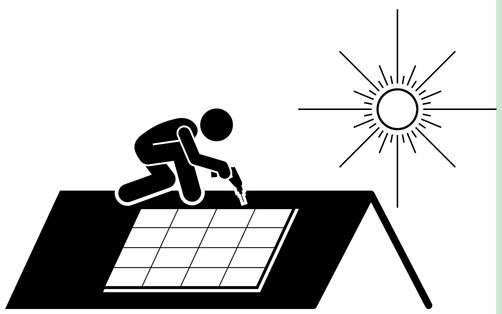
AMPERES

ROOFTOP SOLAR IS BOOMING ACROSS THE WORLD





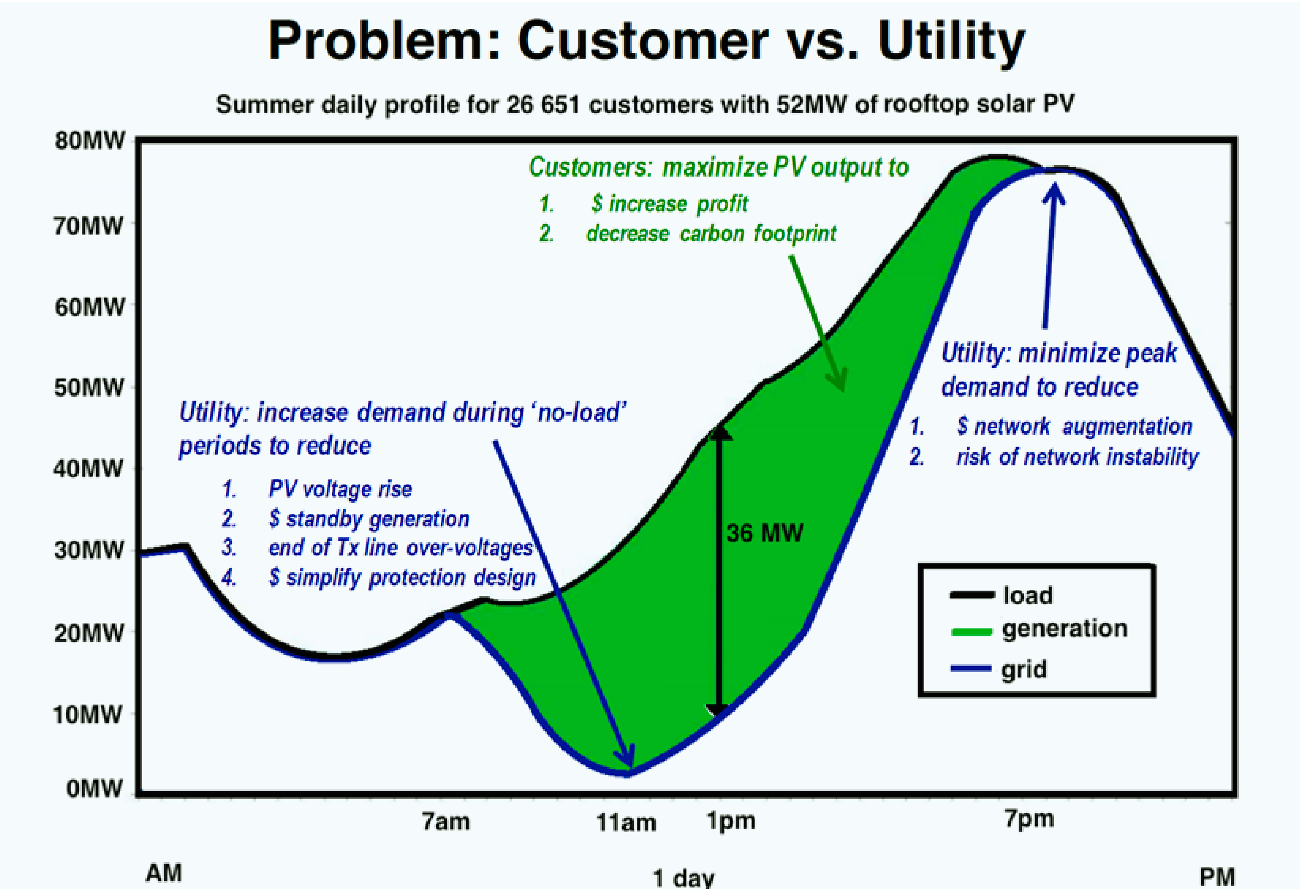
Cumulative PV penetration per capital.
Data source: IEA, 2021. Trends in Photovoltaic Applications 2021.

The falling prices of solar PV has seen PV installed at utility scale solar farms but also behind the meter on commercial & residential rooftops.

In countries like Australia, Germany and the US, rooftop solar installations have increased 10 – 100 times over the past decade as energy consumers seek to reduce electricity bills, increase profit and decrease their own carbon footprint.

THE DUCK CURVE PROBLEM: CUSTOMER VS UTILITY

As installation of rooftop solar increases, it causes a change in the demand profile. Solar generation reduces the demand for electricity during sunlight hours (the duck curve) whist requiring grid electricity during peak hours and evenings. The duck curve creates a new demand profile for grid operators to manage.



Summer daily profile of 26,651 customers with 52 MW of rooftop solar PV.

- During peak solar generation: voltage instability and the need for flexible generation that can be ramped up on cloudy days and ramped down on sunny days
- During the evening demand peaks: rise of network instability and peaking generation

OPTIONS TO MANAGE THE DUCK CURVE

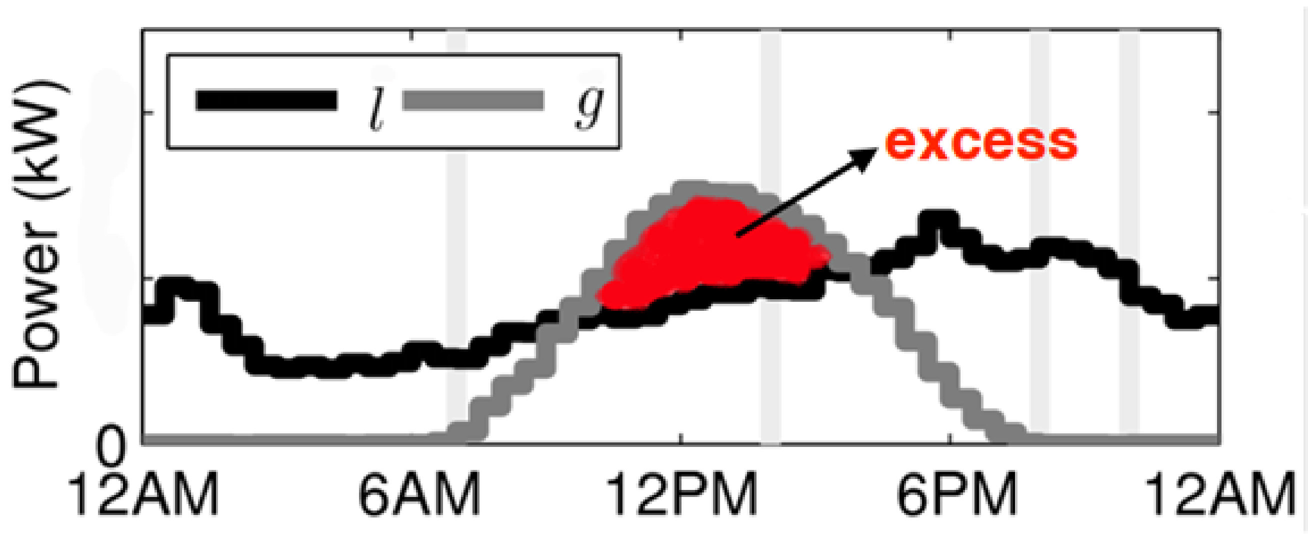
1. Individual residential systems
2. Coordinated residential systems
3. New control paradigms

1

INDIVIDUAL RESIDENTIAL SYSTEMS

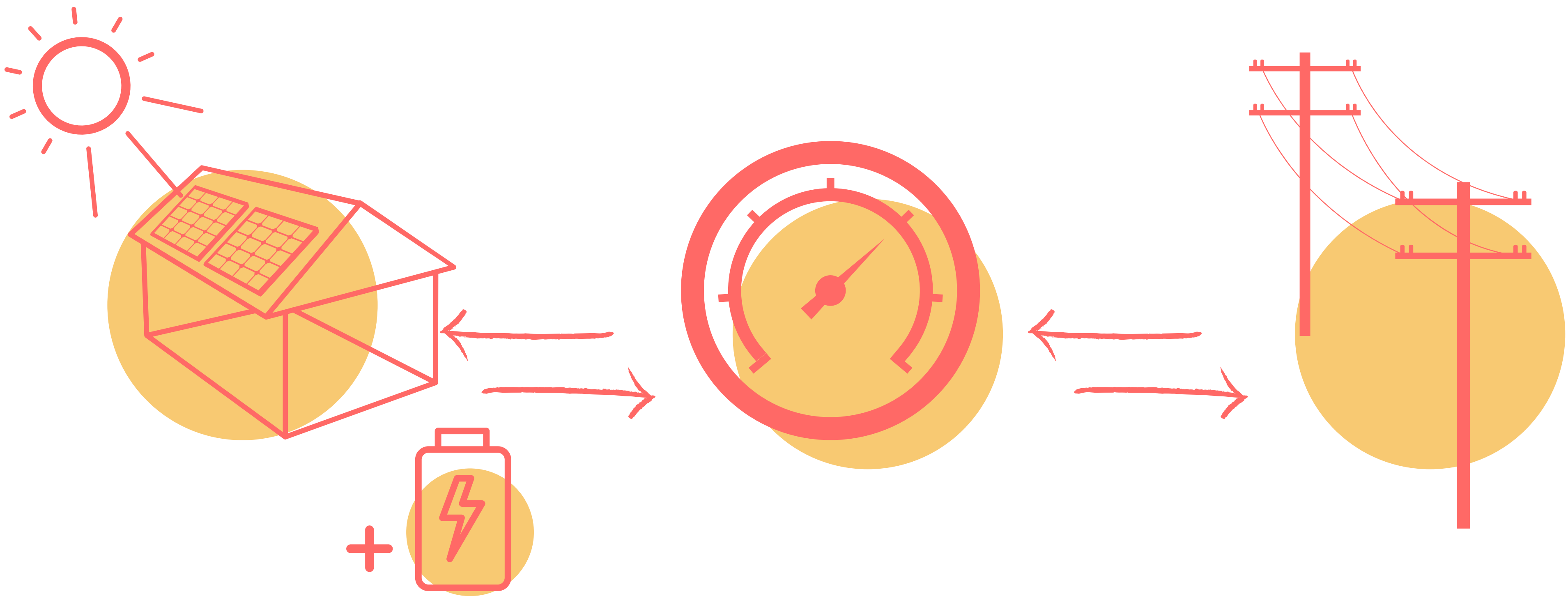
Considering a single resident system, there is a certain time during the day when the electricity generation exceeds the load.

The excess can be **exported to the grid** or can be **stored in a battery.**



Power generated from rooftop solar systems exceeds the demand around midday.
Note: l: load; g: generation

NET METERING AND TIME-OF-USE PRICING

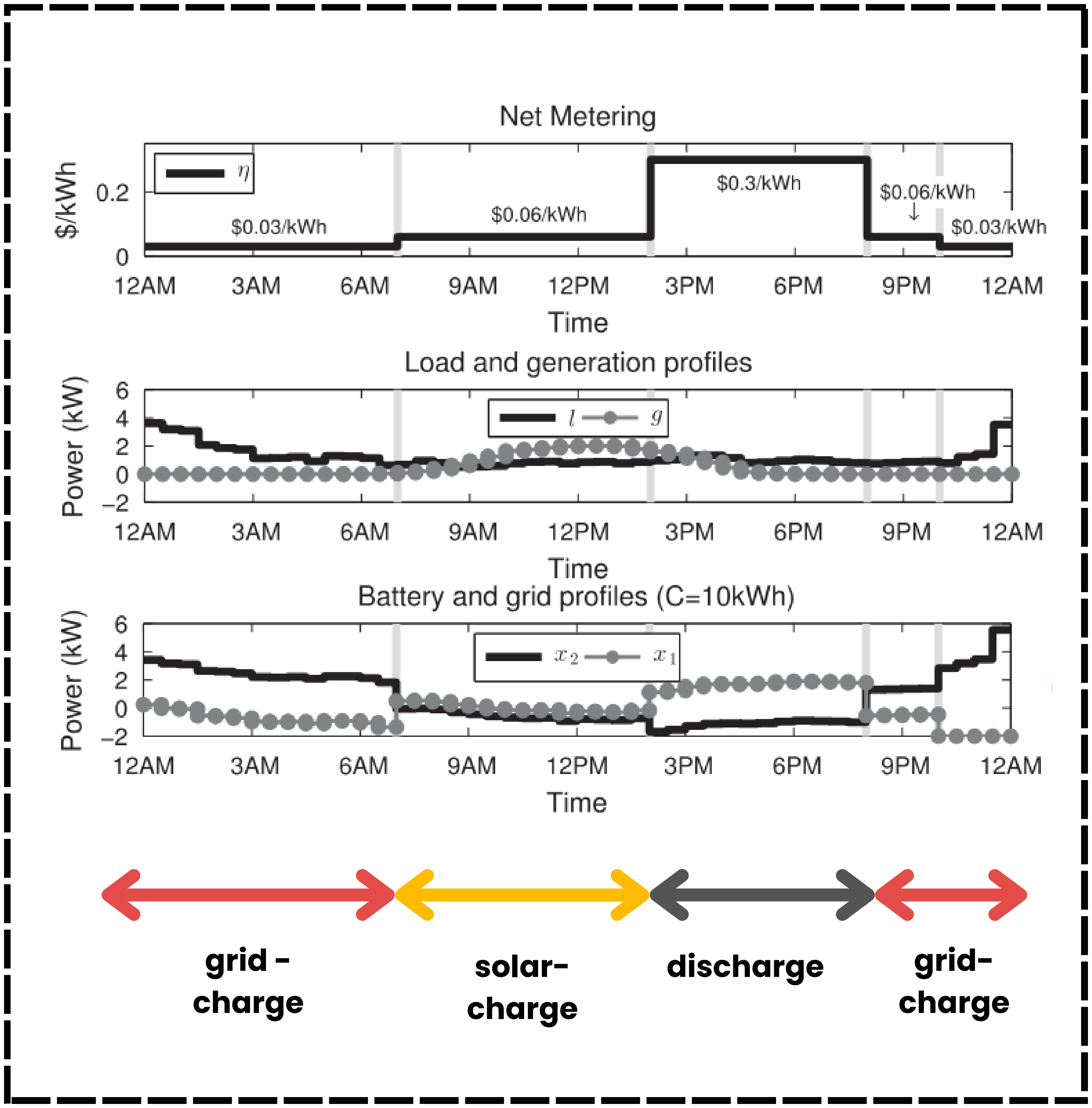


Net-metering provides incentive for consumers to install roof top solar by allowing direct consumption of solar and export of excess generation to the grid, typically at a fixed feed-in-tariff.

Time-of-use (TOU) pricing differentiates the cost of electricity based on peak and off-peak tariffs. This provides an incentive for consumers to add batteries to their solar system and coordinate their charging schedule to maximise the benefit in accordance with the variation in electricity price during the day.
For the grid, TOU has the benefit of reducing grid consumption during peak times and reducing solar exports during the peak times alleviating the duck curve.

SCHEDULE USE OF BATTERIES AND GRID ELECTRICITY TO MAXIMISE SAVINGS

Exploiting the variation in electricity price at different times of the day, a consumer can charge their battery during off-peak times when the price is low and discharge their batteries during peak pricing times.

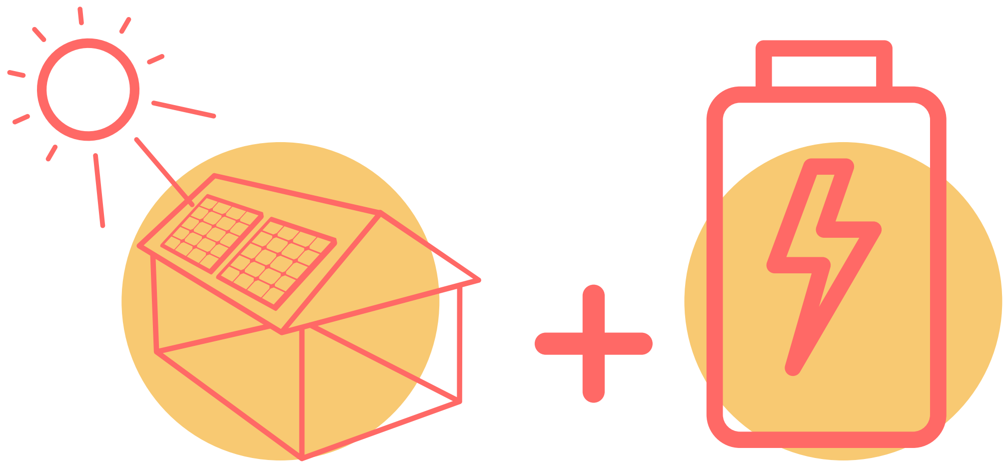


Financial policy, load and generation profiles, and grid and battery profiles for a battery of 10 kWh.
Note: l: load; g: generation; x1: battery profile with x1<0 = charge, x1>0 = discharge; x2= grid profile.

Souce: EL Ratnam, SR Weller, CM Kellett, "Scheduling residential battery storage with solar PV: Assessing the benefits of net metering," Applied Energy, 2015

CASE STUDY

A case study of 145 residential customers located in an Australian distribution network shows that applying this strategy would save them **986 AUD** annually.



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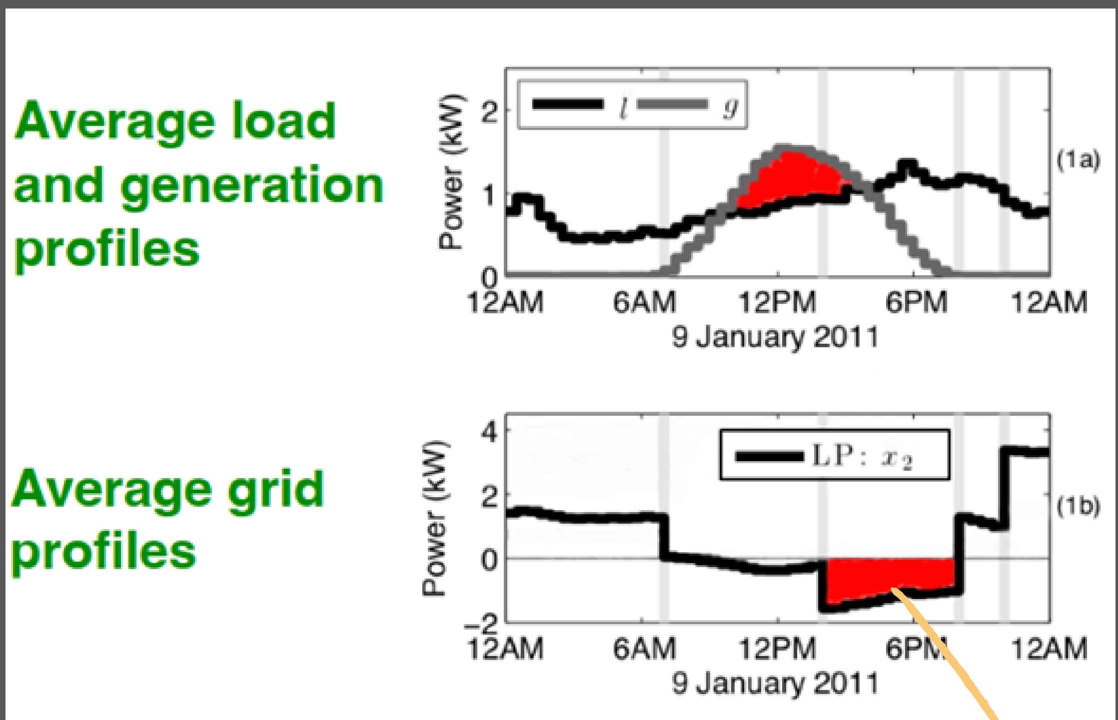


Reverse power load

BUT..

As more customers adopt this individual battery schedule, the cumulative effect can lead to reverse power flow and voltage rise in the network.

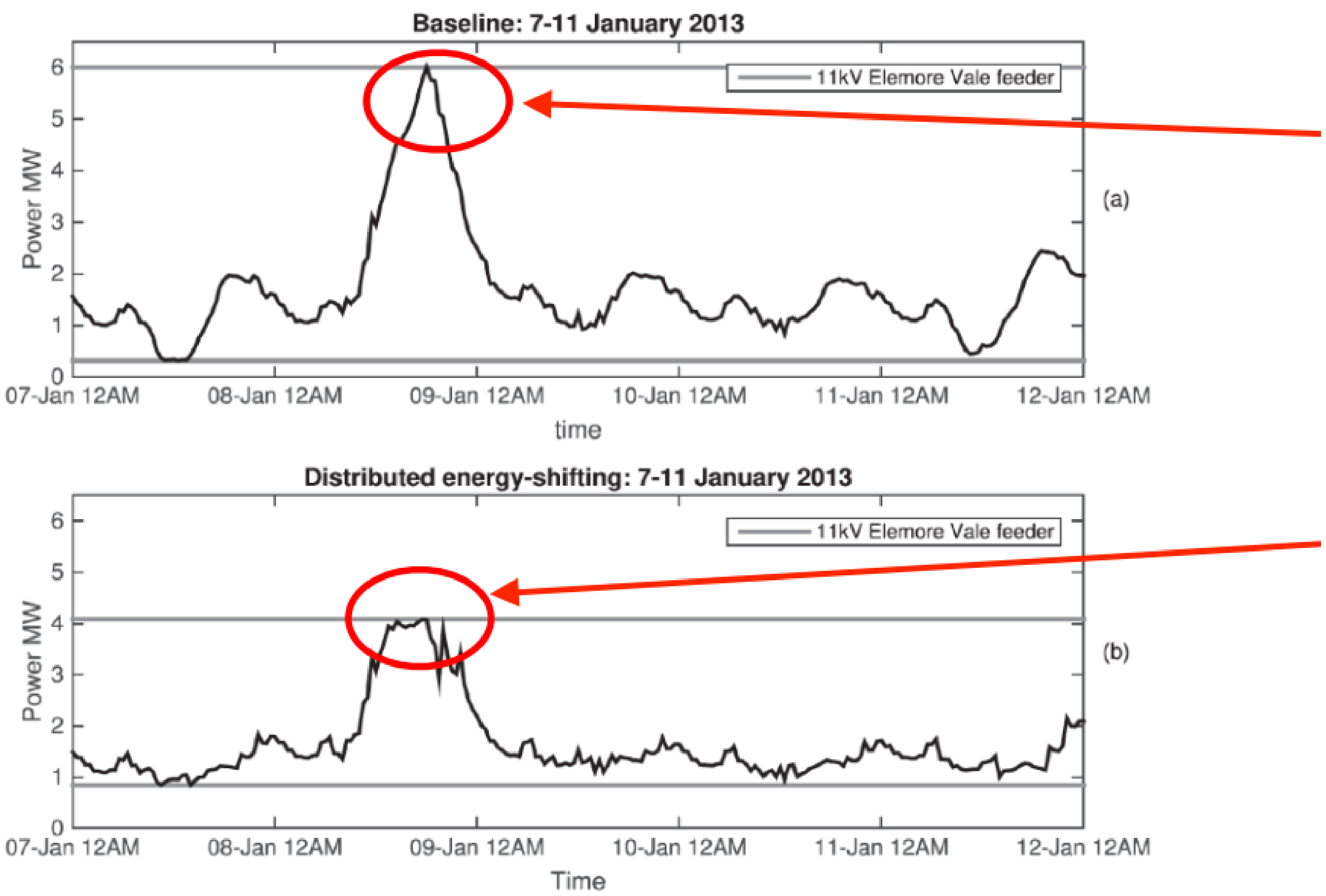
2

COORDINATED RESIDENTIAL SYSTEMS

A coordinated schedule seeks to retain the consumer benefits of solar battery systems whilst mitigating the emergent grid reliability issues.

The grid operator specifies the battery charging schedule a day ahead, effectively coordinating multiple distributed renewable energy assets for optimal system operation.

Peak load reduction of 2MW



Baseline (no battery)

Centrally coordinated residential systems

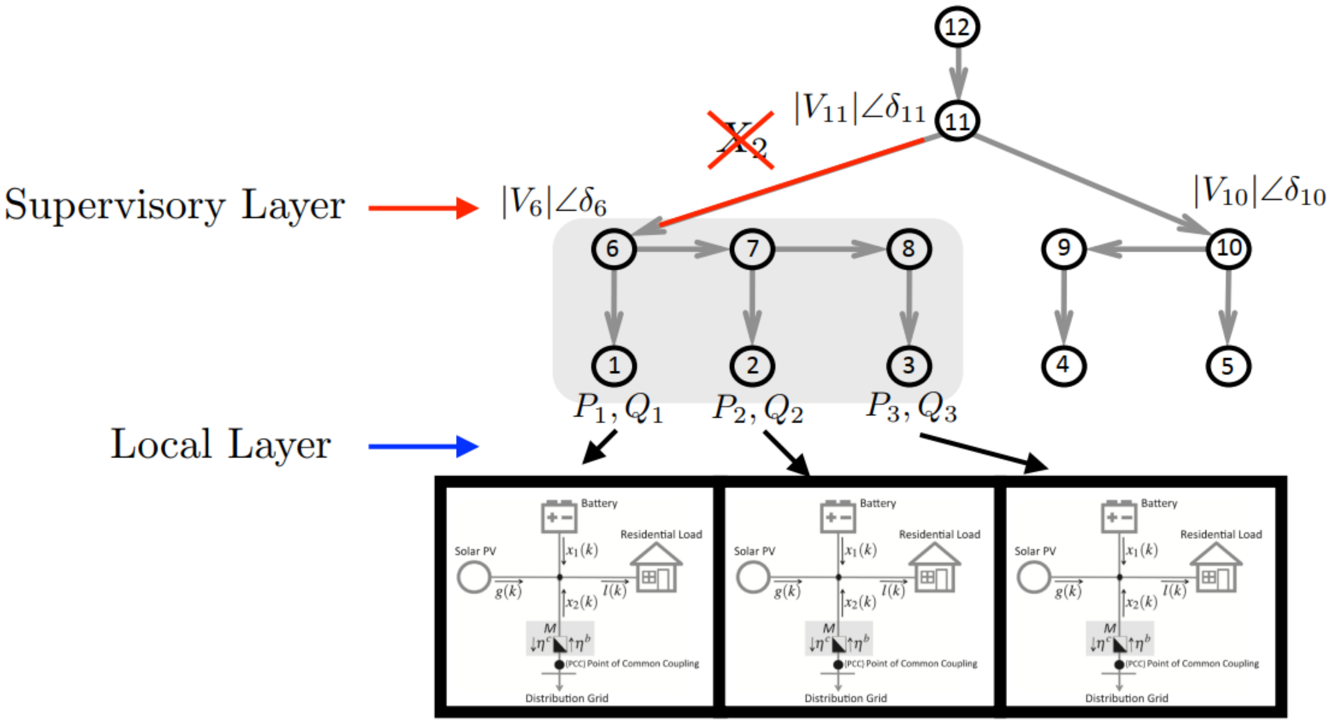
EL Ratnam, SR Weller, "Receding horizon optimization-based approaches to manage supply voltages and power flows in a distribution grid with battery storage," Applied Energy, 2018

3

NEW CONTROL PARADIGMS - SYNCHROPHASES

Synchronized phasors (synchrophasors) provide a real-time measurement of electrical quantities from across the power system.

They can be used to control voltage in all lines of the distribution network to optimse grid reliability with increased consumer roof top solar through: (1) phase balancing and (2) adaptive islanding.



Source: Phasor-Based Control for Scalable Integration of Variable Energy Resources, A von Meier, EL Ratnam, K Brady, K Moffat, J Swartz, Energies 13 (1), 190

Rooftop solar with net-metering offers a significant economic benefit to electricity consumers by reducing some grid electricity consumption with self-generated solar. Batteries and time-of-use tariffs extend the potential for consumer savings.

However, there is tension between consumer savings and grid operations. As the number of rooftop solar systems on the grid continues to grow, issues of reverse flows, voltage fluctuations and ultimately network failure can arise.

Managing these issues requires new approaches to coordinating imports from distributed rooftop solar systems which can be supported by new technologies like synchrophasors.

Optimal solutions can be found which provide economic benefits to consumers with rooftop solar while maintaining grid performance and reliability.

NEXT SESSION

ENERGY EFFICIENCY

Dr. Lee White

10:00-12:00 HANOI-JAKARTA TIME
11:00-13:00 MANILA TIME
MAY 18

ETP Round Tables is a two-year capacity building and networking program of the ETP in Indonesia, the Philippines, and Vietnam. The program aims to build awareness and understanding of practical solutions and pathways that can support Indonesia, the Philippines, and Vietnam accelerate their transition to 100% zero-carbon energy.

Over a 24-week structured online training programme, the ETP Roundtables - **Energy Transition Masterclass** will provide a suite of tailored professional forums (training sessions) to enable the exchange of information, develop leadership among the region's energy transition stakeholders, and endow participants with the latest understanding and tools to accelerate energy transition for both policy and market contexts.

See more: https://www.energytransitionpartnership.org/
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